U.S. DEPARTMENT OF ENERGY

SOLAR DECATHLON

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Solar Decathlon 2009
Highlights of Team Innovations and Cutting-Edge Building Technologies

Cornell University

- The house is built around a centralized core with all engineering systems in the mechanical / electrical closet at the center of the house.
- The electrical energy is produced using 40 solar panels yielding 8kW nominally.
- Thermal energy is collected by a system of 30 Silicon Solar SunMaxx U-30 evacuated tube collectors mounted on the south sides of two cylinders; this is the house's primary means of generating heat.
- Exterior of house is CorTen corrugated steel. Copper pipes running behind the corrugations are heated by conduction, which then heats water as it passes in proximity to fill the hot water tank. This system offers instantaneous switching between heating and cooling and provides cooling by using a reverse-cycle chiller.
- Automated variable air volume (VAV) dampers in the ductwork regulate each module's temperature by restricting the airflow through the ducts.
- The controls system monitors and analyzes all of the information coming from each system and relays signals back and forth for control and automation. Industry-grade sensors and equipment provide feedback, which is logged on a centralized server. Information can be displayed on various devices in the house such as the computer, television, or touch-screen panels as well as remotely via a secure encrypted Internet connection.

Iowa State University

- A louver system that tracks the sun based on angle controls the tilt of the window louvers to limit unwanted solar heat. Systems such as this are typically seen only in much larger installations.
- A liquid desiccant system (used to control humidity), integrated with HVAC systems, is computer-controlled and monitored.

Penn State

- Green Roof Integrated PVs, which consist of a dark-blue thin film shaped around a cylinder, enable the solar panels to capture more sunlight throughout the day than traditional flat panels can. Spaces between the cylinders allow light and water to pass through so green plants can blossom.

- The north façade features a "life well," a wall of plants and herbs that grows between the bathroom and the kitchen. Residents can pick basil from inside the kitchen wall for cooking.
- The team developed a thermal mass storage system that uses water bags under the hardwood floor. This pump-less solar hot water system works through changing the properties of water when it is exposed to heat.

Rice University

- The ZEROW HOUSE is organized around two cores. The wet core houses all systems associated with water and energy, placing mechanical and plumbing systems in one central location and linking the kitchen, bathroom, washer and dryer, HVAC, and solar electric systems. This helps reduce costs and materials required for installation and maintenance of mechanical and plumbing systems.
- The "light core" serves as the primary source for daylighting in the house, improves natural light and ventilation, and directly extends the interior living space.
- A green wall attached to the porch side of the house is home to several varieties of noninvasive plants native to the Southeast. The team carefully selected plants that will bloom in different seasons to "warm up" the corrugated metal exterior.

Team Alberta (University of Calgary, SAIT Polytechnic, Alberta College of Art + Design, Mount Royal College)

- A programmable logic controller automatically adjusts blinds, lights, and mechanical systems and can even call for service if there are any problems.

Team Boston (Boston Architectural College, Tufts University)

- A monitoring system tracks energy use in real time to allow homeowners to make adjustments that will reduce their energy bills and environmental impact. It also provides instant information through a visible ambient feedback system inside the house.
- Curio.House features water-filled windows that act as a thermal mass to help regulate indoor temperatures. The windows capture heat from the sun during the day and then slowly release the heat at night, warming the interior of the house. Shades also control how much heat comes into the home.
- A 6.4-kW photovoltaic system uses micro-inverters on each panel for flexibility in repairing, replacing, modifying, and expanding the system.

Team California (Santa Clara University, California College of the Arts)

- Refract House is a bent tube that controls the entry of light. The tube—wrapped around a central courtyard—is essentially cracked in three places, resulting in modules for the living room, kitchen, and bedroom areas.
- The two ends of the house are cantilevered, with one end floating over a rainwater pond and the other one floating above the ground.
- The system integration of Refract House is transparent. An iPhone application allows occupants to instantly modify energy use; a dashboard monitors and displays the house's energy and water consumption on a user-friendly Web interface.
- The house features a "cool roof" design, where solar panels are racked high above the roof, and the walls are covered with a weather-stopping "skin." Both of these systems allow airflow, prevent solar gain, and shield the house from the elements for a longer life.

Team Missouri (Missouri University of Science & Technology, University of Missouri-Columbia)

- The Show-Me House is governed by a modular, three-foot grid, on which everything connects, leaving the design simple for construction and unifying the interior and exterior.
- To provide both convenience and increased building end-use efficiency, the team developed a hybrid automation and energy management system called Chameleon. Touch screens in the bedroom and main entrance control many functions, including HVAC, lighting, window and shade control, home entertainment, appliances, and power monitoring.

Team Ontario/BC (University of Waterloo, Ryerson University, Simon Fraser University)

- To meet the challenges of varying sun angles, North House combines rooftop PV panel and solar thermal systems, with extensive vertically mounted PV on its exterior, to capture low-angle and winter sun.
- North House is designed with a responsive envelope. Highly insulated floor-to-ceiling glass is protected from summer sun by operable exterior sun shades that retract to allow passive solar gain and maximize daylight during winter months.
- A unique control and interface system allows users to easily operate the home's dynamic features and maintain comfort, while providing feedback and energy reduction incentives through custom-designed in-home and online applications.

Team Germany (Technische Universität Darmstadt)

- The house's single-room concept allows for the whole space to be conditioned by air with a simple distribution system.
- The building envelope uses highly efficient thermal insulation, opaque walls and windows. To avoid heat bridges, high-efficiency vacuum insulation panels were mounted on top of the wooden construction.
- The PV modules installed on the façade and on the roof will collect more energy than necessary to run the electronic equipment. Two types were used: mono crystalline silicon on the roof (18% efficiency) and thin-film CIS cells (11% efficiency). These cells have a lower efficiency but they have fewer problems with increasing temperature and have better performance in cloudy weather.
- The heating, cooling, and hot water system uses a reversible heat pump that features mechanical ventilation for heat recovery, dehumidification in cooling cases, and the possibility to supply hot water and cooling at the same time.
- For the reduction of heating and especially cooling loads, phase change materials (PCM) were placed inside the gypsum boards on the walls and inside the cooling system in the ceiling. This buffers temperature peaks and allows the use of cool air in the night to discharge stored heat energy.

Team Spain (Universidad Politécnica de Madrid)

- A squat, inverted glass pyramid serves as a top roof for the house. Containing both PV modules and solar thermal collectors, it pivots on a ball-and-socket joint to track the sun. The university has filed for a patent on the ball-and-socket pivot system.
- Much of the house's daylighting enters from above, either passing down through the open tip of the pyramid or reflecting off the sides of the pyramid through skylights in the lower roof.
- High-performance sandwich panels in the façade comprise thermal panels, PV glass panels and an air chamber.

The Ohio State University

- A trombe wall relies on the thermal storage capacity of water rather than a solid mass so that light is still permitted in the space.
- Bifacial photovoltaic panels allow sunlight hitting the house through or around the arrays to be reflected back up by the white roof membrane. The light then hits the backs of the solar cells, which enhances the efficiency of the overall system.
- 6.84 kW solar panel array consists of 36 190-W Sanyo Bifacial PV panels

- A PV rack system from Direct Power and Water with Unistrut® tracks is very adjustable so the optimum solar panel configuration in any geographic location and any season can be achieved.
- Highly reflective roof surface also reduces cooling loads in summer months.
- The sun heats the domestic water supply and radiant floor hydronic system with an Apricus 30-tube evacuated tube array and a nonpressurized drain-back system, which is stored in a well-insulated hot water tank.
- Radiant floor consists of Warmboard™ subflooring with an integrated aluminum plate and channels for increased heat transfer and improved transient response. Three high-efficiency Grundfos pumps are used in conjunction with a controller from Tekmar to create an injection mixing system that varies both the temperature of the water and the flow rate to each zone of the radiant floor.
- Three mini-split heat pumps are used for cooling and backup heating.
- Home automation system will monitor and control lighting, appliances, HVAC equipment, the PV array, and the solar thermal hot water heating system. The home automation system is based on the BuildingLogiX™ interface and the NiagaraAX Framework®.

The University of Arizona

- A water wall, developed as part of a student's thesis project, provides heat storage during the day and space heating at night.
- The roof and attached solar panels can rotate to optimize energy collection regardless of the house's geographic location.
- An air plenum, or cavity, lies beneath the south wall and is equipped with bifacial PV panels that pick up ambient light and improve efficiency of the overall system. The plenum helps draw hot air out of the house through a passive convective system.
- The structural south wall and roof are made of one continuous sheet of laser-cut and folded steel that is lifted into place, creating a "C" shape for the house.

Universidad de Puerto Rico

- Steel L-shaped design of the house eases transportation from Puerto Rico to D.C.
- An evacuated tube solar collectors system is used for solar thermal water heating. The system absorbs thermal energy from the sun, converting it into usable heat that is normally absorbed by water.

University of Illinois at Urbana-Champaign

- The house will be Passive House Certified, meaning it will consume 90% less electricity for heating and cooling than a standard house.
- An energy recovery ventilator system essentially captures cool air in the summer and warm air in the winter and transfers this energy to the fresh air supply, reducing the energy required to condition the air.
- The structural system is made from laminated bamboo or "lamboo," a rapidly renewable lumber that offers 10 times the strength of typical framing wood.
- The house’s PV system consists of 40 panels that fill the southern roof to achieve 6,000W DC power rating for the system. Each array connects to a SunPower 5000m inverter
- The HVAC system relies on conditioning the air with a heat recovery ventilator (HRV) or energy recovery ventilator (ERV) to achieve minimum ventilation requirements.
- The envelope of the house is super insulated, with windows placed on the south-facing wall to maximize solar heat gain during the winter while limiting the windows on the other three walls.

University of Kentucky

- The team designed a large, custom-integrated house operating system that reads temperatures in the house, incorporates weather forecasts, communicates how energy is used, and advises the homeowner on how to optimize the performance of the systems.
- The custom-designed air-to-water heat pump heats hot water even when outside temperatures are near freezing.
- The HVAC system comprises a high-efficiency reverse-cycle chiller coupled with a small thermal storage tank to provide hot water for floor heating and cold water for air conditioning and dehumidification.
- PV rack can be tilted for seasonal adaptation and maximum solar energy collection.

University of Louisiana at Lafayette

- The transitional porch features a NanaWall® door system, designed by the team, which rotates 360 degrees to allow the space to be open as an exterior porch that cools the home passively. The doors also rotate to close the porch and expand interior spaces, creating a larger living room.
- The house incorporates geographically relevant, hurricane-resistant design choices such as sliding, louvered shutters on south-facing windows and structural insulated panels as the building envelope. A solar thermal system in the roof of the transitional porch does double duty by providing shade and absorbing the sun's rays to heat hot water. The university is seeking a patent for this unique solar thermal system, which is enclosed by polygala a material built to withstand hurricanes.
- All doors and windows have eco shades that allow people to see out but not in. Motorized mosquito screens roll down and double as UV and privacy screens. In the transitional porch, BeauSoleil's exterior cladding is a rain-screen system that allows air to circulate between the siding and the wall, minimizing heat from the sun, providing additional insulations, and ventilating the space between the siding and the structure.

University of Minnesota

- The house takes advantage of as much "free" heating from passive solar sources as possible and also creates a tight envelope that keeps heat from escaping.
- Radiant, under-floor heating uses hot water supplied by flat-plate solar collectors to heat the house in winter and recharge an innovative desiccant dehumidification system in summer.
- A PV system consisting of traditional roof-mounted PV panels and translucent bifacial panels includes different inverters for different types of PV panels and orientations. With this design, panels that produce less won't draw down the whole system.
- Building Integrated Photovoltaic (BIPV) glazing is located on the east end of the south wall and roof, allowing some light to pass for natural illumination while converting some to electricity.
- External wall sections are insulated with R-values between 50-60 BTU/hr-ft^2 to reduce conductive heat loss.
- Windows have triple-pane glazing that uses low-emittance coatings and are filled with inert gas to minimize convective and radiative heat loss.
- An eastern eave and louvers reduce the direct solar heat gain through the east kitchen window.

University of Wisconsin-Milwaukee

- The inverted, butterfly-shaped roof of the house is inspired by the landforms created by glaciers.
- Staggered stud walls, made with two-by-fours, create more room for insulation and reduce heat transfer.
- Rather than integrating PV panels into the roof, this house raises the panels upward to highlight them as an important component of the project and overall design.

Virginia Tech

- Lumenhaus offers a demonstration of “responsive architecture.” All of the systems—heating, cooling, the PV array, and even the large insulation panels—are operated by the house computer, which receives and interprets weather data. The system can also be operated by an iPhone allowing the homeowner to override the system based on personal comfort preferences.
- Movable wall systems of insulation panels and shading screens perform a large portion of the heating and cooling functions through passive systems. Sliding polycarbonate doors filled with nanogel can slide open or close for heat gain or loss.
- As part of the wall system, the screens provide natural daylighting, shading, and ventilation, while louvers block out sun to stop overheating.
- The house features a 4.5-in (0.1-m) concrete floor that provides passive, radiant heating. The radiant system makes use of RAUPEX™ O2 Barrier Piping, which is a highly flexible pipe with enhanced temperature transfer capability.
- The house’s geothermal heat exchanger system is essentially a large pool of water that provides energy to the water circulating through.